

Attorney Docket No. 82867  
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**INLET FREE TORPEDO LAUNCH SYSTEM**

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT THOMAS J. GIESEKE, citizen of the United States of America, employee of the United States Government, resident of Newport, County of Newport, State of Rhode Island, has invented certain new and useful improvements entitled as set forth above of which the following is a specification:

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1 Attorney Docket No. 82876

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3 **INLET FREE TORPEDO LAUNCH SYSTEM**

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5 **STATEMENT OF GOVERNMENT INTEREST**

6 The invention described herein may be manufactured and  
7 used by or for the Government of the United States of America  
8 for governmental purposes without the payment of any royalties  
9 thereon or therefor.

10

11 **BACKGROUND OF THE INVENTION**

12 (1) Field of the Invention

13 The invention generally relates to a launch system and  
14 more particularly to a launcher which eliminates the need for  
15 an inlet door for a supply of fluid for launch by using an  
16 alternatively configured fluid flow.

17 (2) Description of the Prior Art

18 The current art for torpedo launch systems with a  
19 pressurizing pump have a "U" configuration where one end of  
20 the "U" is a flow intake, the bottom of the "U" contains the  
21 pump, and the other end of the "U" is the torpedo tube. To  
22 operate, the intake end of the launch system includes a large  
23 and complex hydraulically actuated door.

24 A prior art turbine pump ejection system (TPES) 100 is  
25 shown, by way of example, in FIG. 1 of the drawings. The  
26 turbine pump ejection system 100 includes an inlet door 102  
27 opening to an inlet recess 104. The inlet recess 104 supplies

1 seawater as the system fluid to an inlet cylinder 106 as a  
2 result of a turbine pump 108 drawing seawater into the inlet  
3 cylinder and pumping seawater into an impulse tank 110,  
4 through a slide valve 112, down a torpedo tube 114, through a  
5 shutterway recess 116, and out of the platform via a primary  
6 shutterway 118.

7 In operation, the inlet door 102, the slide valve 112,  
8 the primary shutterway 118 and a secondary shutterway 120 are  
9 opened to create an open flow path through the launch system  
10 100.

11 Prior to launch, the pressure in the inlet recess 104 and  
12 the pressure in the shutterway recess 116 each independently  
13 increase to some fraction of the available dynamic head, as a  
14 result of forward motion of the system through the ocean. Any  
15 imbalance between the pressure in the inlet recess 112 and the  
16 shutterway recess 116 causes fluid in the launch system, and  
17 any device in the torpedo tube 114, to move.

18 When a launch is initiated, the turbine pump 108 begins  
19 to rotate and fluid is drawn through the inlet door 102, the  
20 inlet recess 104, the inlet cylinder 106 and into the turbine  
21 pump 108. The turbine pump 108 pumps fluid into the impulse  
22 tank 110, through the slide valve 112, down the torpedo tube  
23 114 carrying the weapon in the torpedo tube through the  
24 shutterway recess 116 and out of the system 100 via the  
25 primary shutterway 118.

26 The following reference, for example, discloses an  
27 external fluid intake apart from the operating launch tube,

1 but does not disclose an internally circulating fluid path  
2 which eliminates an inlet door.

3       Wosak (U.S. Patent No. 2,837,971) discloses hydraulic  
4 ejection equipment for missiles. Specifically, the reference  
5 discloses a system having a water-filled cylinder  
6 communicating at one end with the sea and communicating at its  
7 other end, through ports in its walls and a passageway or  
8 conduit, with the aft end of a missile ejector tube whose fore  
9 or discharge end communicates with the sea. A piston is  
10 mounted for reciprocating movement in the water cylinder with  
11 the piston is connected to a suitable driving mechanism for  
12 moving the piston from its retracted position to force water  
13 ahead of the piston through the ports in the forward end of  
14 the water cylinder though the conduit connecting those ports  
15 with the aft end of the missile ejector tube thereby to charge  
16 the water into the ejector tube and behind the missile in the  
17 tube and in a sufficient amount and with sufficient force to  
18 expel the missile from the tube with a force and velocity.

19       It should be understood that the present invention would  
20 in fact enhance the functionality of the launching systems by  
21 providing a launcher design which eliminates the need for an  
22 intake door.

23

#### 24                   **SUMMARY OF THE INVENTION**

25       Accordingly, it is a general purpose and primary object  
26 of the present invention to provide a launcher system with a  
27 fluid intake door eliminated as a component of the launcher.

1        It is a further object of the present invention to  
2 provide a launcher system which provides a common path for  
3 fluid intake and vehicle exit.

4        It is a still further object of the present invention to  
5 provide a launcher which corrects reverse fluid flow in  
6 existing systems.

7        In accordance with one aspect of the present invention,  
8 there is provided an inlet free launcher system including an  
9 inlet recess in fluid communication with a shutterway recess.  
10 A primary shutterway is provided both for ejection of a  
11 vehicle and for supplying fluid intake to the system. A pump  
12 selectively circulates fluid from the inlet recess to the  
13 shutterway recess, and a launch tube houses the vehicle, such  
14 as a weapon, within the system prior to launch thereof. A  
15 slide valve and impulse tank combination are positioned  
16 intermediate the pump and the launch tube, such that the slide  
17 valve controls a flow of fluid to the launch tube. A guide  
18 can is positioned in the shutterway recess for guiding the  
19 vehicle from the launch tube to an exterior of the launcher  
20 and fluid within the system is continually moderated to enable  
21 selective launch of the vehicle with a fluid force.

22

23                    **BRIEF DESCRIPTION OF THE DRAWINGS**

24        The appended claims particularly point out and distinctly  
25 claim the subject matter of this invention. The various  
26 objects, advantages and novel features of this invention will  
27 be more fully apparent from a reading of the following

1 detailed description in conjunction with the accompanying  
2 drawings in which like reference numerals refer to like parts,  
3 and in which:

4 FIG. 1 is a schematic of a prior art turbine pump  
5 ejection system for launching a device;

6 FIG. 2 is a schematic of a launcher for an underwater  
7 environment according to a preferred embodiment of the present  
8 invention;

9 FIG. 3 is a schematic of Phases 1 and 2 of a launch  
10 operation of the launcher of the present invention;

11 FIG. 4 is a schematic of Phase 3 of the launch operation  
12 by the launcher of the present invention;

13 FIG. 5 is a schematic of Phase 4 of the launch operation  
14 by the preferred embodiment of the present invention;

15 FIG. 6 is a schematic of Phase 5 of the launch operation  
16 by the preferred embodiment of the present invention;

17 FIG. 7 is a graph relating pump speed and flow rates in  
18 support of the present invention;

19 FIG. 8 is a graph relating performance of pump head and  
20 time in support of the present invention;

21 FIG. 9 is a graph showing parameters associated with a  
22 launchable vehicle entering a guide can of the launcher of the  
23 present invention; and

24 FIG. 10 is a graph depicting a comparison of base-line  
25 system performance of the prior art and modified system  
26 performance of the launcher of the present invention.

1                   **DESCRIPTION OF THE PREFERRED EMBODIMENT**

2           In general, the present invention eliminates the need for  
3 a conventional intake door by utilizing a D-shaped launcher 10  
4 as shown in FIG. 2. The launcher 10 is referred to;  
5 hereinafter, as a shutterway intake launcher (SIL) because the  
6 fluid intake and the exit for a torpedo or an unmanned vehicle  
7 share the same communication path with the ambient underwater  
8 environment.

9           In further description, the overall structure of the  
10 shutterway intake launcher 10 includes an inlet recess 12  
11 having recess communication holes 14 formed in a wall thereof.  
12 The inlet recess 12 supplies fluid to an inlet cylinder 16  
13 upon actuation of a pump 18. The pump 18 pumps the fluid into  
14 an impulse tank 20, through a slide valve 22, down a launch  
15 tube 24, through a shutterway recess 26 and through a primary  
16 shutterway 28. A secondary shutterway is shown as component  
17 30 in fluid communication with the other component of the  
18 launcher 10.

19           The recess communication holes 14 penetrate a wall of the  
20 inlet recess 12 which defines a corresponding wall 31 of the  
21 shutterway recess 26 such that the shutterway intake launcher  
22 10 relies on the intake of fluid through either the primary  
23 shutterway 28 or the open secondary shutterway 30 due to the  
24 absence of an inlet door in the inlet recess 12. In other  
25 words and as will be described below, fluid collected in the  
26 shutterway recess 26 is supplied to the inlet recess 12 via  
27 the recess communication holes 14.

1 By way of general understanding, the launch tube 24 is  
2 the back of the "D" and the loop of the "D" is a re-  
3 circulating water path containing the pump 18. In effect, the  
4 fluid intake and vehicle or torpedo exit share the same  
5 communication path with the ambient environment.

6 Several aspects of the invention have been examined using  
7 analytical and numerical techniques. Of primary interest is  
8 the impact of added mass and loss to the existing flow system.  
9 Based on the calculated results, it is estimated that there  
10 will be minimal changes to the operation of the turbine pump  
11 18 and the basic dynamics of torpedo launch will be unaffected  
12 by the proposed system changes.

13 Continuing with the description, the shutterway intake  
14 launcher 10 operates by the intake of fluid through either the  
15 operating launch tube (primary shutterway 28) or the open  
16 second shutterway 30 to compensate for the loss of fluid flow  
17 due to the absence of an inlet door. Furthermore, the  
18 shutterway intake launcher 10 operates largely free from pre-  
19 launch reverse flow (the system can be pressure-balanced as  
20 much as is possible without eliminating leakage flow), such  
21 that the launcher does not require an inlet door.

22 The functioning and operation of the shutterway intake  
23 launcher 10 is largely controlled by several performance  
24 related phenomenon. These phenomenon include changes in  
25 performance of the turbine pump 18 as a result of flow-path  
26 changes; effectiveness of pressure balancing due to a closed  
27 system operation; launch transient changes as a result of



1 flow-path changes; changes in launch dynamics as a result of  
2 launch jet elimination; and changes in flex hose cable  
3 dynamics as a result of flow path changes.

4       The first four of the above phenomena are addressed by  
5 formulating a launch system performance model using first  
6 principle hydrodynamics concepts. The governing equations for  
7 such a model are: conservation of mass, applied at each  
8 location where flow streams converge; Newton's equation of  
9 motion applied for each fluid mass; Darcy's equation for flow  
10 loss applied across each flow restriction; Newton's equation  
11 of motion applied for the motion of the vehicle; and an  
12 experimental model for transient pump performance.

13       Although some simplifications are made regarding forces  
14 during these transient launch phases, they serve as a primary  
15 model for the shutterway intake launcher 10.

16       FIGS. 3 through 6 illustrate the phases of the launch  
17 process including positioning of a vehicle 32, such as a  
18 weapon, within the launch tube 24. The arrowheaded lines in  
19 the figures indicate a flow of fluid through the shutterway  
20 intake launcher 10, while the sequence bubbles correspond to  
21 the equations below.

22       Phases 1 and 2 are shown in FIG. 3. Phase 1 is the pre-  
23 launch phase of the operation of the shutterway intake  
24 launcher 10. During the pre-launch phase, the pump 18 is not  
25 actuated but the entire flow path is open. A dynamic head  
26 recovered in the shutterway recess 26 drives fluid through the  
27 launcher 10. Under these conditions, the pump 18 serves as a

1 flow restriction and is not a source of energy. Other than  
2 this slight deviation, the system operates identically as it  
3 does in Phase 2 (description to follow) until the weapon 32  
4 contacts the aft end of the torpedo tube or moves forward out  
5 of the launch tube 24.

6 Phase 2 is the initial acceleration of the vehicle 32.  
7 During this phase of the launch operation, the turbine pump 18  
8 (see FIG. 2) begins to increase speed. The head developed by  
9 the pump 18 is a function of the speed, the flow rate and the  
10 transient operating characteristics of the pump. FIGS. 7 and 8  
11 show the performance of the pump 18 as compared to known  
12 parameters. FIGS. 7 and 8 are reflective as a guide to the  
13 head of the pump 18 versus speed input to the launch operation  
14 which determines the relationship between the pressure at  
15 points of the inlet cylinder 16 and the impulse tank 20.

16 In Equation (1), two fluid paths are considered. One  
17 path is directly from the launch tube 24 to the guide can 34  
18 and one from the launch tube 24 to the shutterway recess 26  
19 and then back to the launch tube 24.

20 
$$\frac{dQ_{4,6}}{dt} + \frac{dQ_{5,6}}{dt} = \frac{dQ_{6,10}}{dt} + - \frac{d^2V_6}{dt^2} \quad (1)$$

21 Conservation of mass is applied in the shutterway recess  
22 26, and in the inlet recess 12. The rate of volume change  
23 (dV) of the shutterway recess 26 is equal to the flow (Q) out  
24 of the launch tube 24 and into the shutterway recess 26, less  
25 the flow out of the shutterway recess 26 and into the inlet

1 recess 12 and the flow out of the shutterway recess 26 through  
2 the two open shutterways, i.e.:

$$3 \quad Q_{4,5} = Q_{5,6} + Q_{5,1} + Q_{5,8} + Q_{5,9} - \frac{dV_5}{dt} \quad (2)$$

4 or in differential form

$$5 \quad \frac{dQ_{4,5}}{dt} = \frac{dQ_{5,6}}{dt} + \frac{dQ_{5,1}}{dt} + \frac{dQ_{5,8}}{dt} + \frac{dQ_{5,9}}{dt} - \frac{d^2V_5}{dt^2} \quad (3)$$

6 The rate of volume change (dV) of the shutterway recess  
7 26 is incorporated to account for motion of the vehicle 32 out  
8 of the shutterway recess 26 and into a guide can 34. The rate  
9 of volume change may also be used to incorporate accumulator  
10 effects in the cavity. Leakage to other non-pressure hull  
11 regions in the forward end of the ship has been included.  
12 Conservation of mass must also be addressed in the guide can  
13 34.

14 The flow at the intake of the pump 18 is equal to the sum  
15 of the flow through the inlet recess 12 and from the  
16 shutterway recess 26. In differential form this can be  
17 expressed:

$$18 \quad \frac{dQ_{1,2}}{dt} = \frac{dQ_{6,1}}{dt} + \frac{dQ_{5,1}}{dt} + \frac{dQ_{5,1}}{dt} - \frac{d^2V_1}{dt^2} \quad (4)$$

19 The differential form, Equations (1) and (4), is useful  
20 when relating the flow rates to flow accelerations.

21 Flow through each portion of the shutterway intake  
22 launcher is controlled by the pressure (P) acting over that  
23 portion, the mass in the respective portion, and the loss  
24 through the portion. It can be shown that the flow rate (Q)

1 from a starting point (A) to an end point (B) can be expressed  
 2 as:

$$3 \quad P_A - P_B - \frac{k_{A,B}\rho}{2A^2} Q_{A,B}^2 \left[ \frac{Q_{A,B}}{\|Q_{A,B}\|} \right] - \frac{l_{A,B}\rho}{A} \frac{dQ_{A,B}}{dt} = 0 \quad (5)$$

4 (P) is the pressure with the third term in this  
 5 expression being the flow loss, which includes a loss  
 6 coefficient  $k$ , the flow area  $A$  and the fluid density  $\rho$ . The  
 7 fourth term is the flow acceleration, which includes the  
 8 effective section length  $l$ , the flow area, and the fluid  
 9 density. If the pipe sections between points A and B contain  
 10 sections with different flow areas, effective loss and mass  
 11 terms can be incorporated into Equation (5). The effective  
 12 loss  $K_{A,B}$  is given by

$$13 \quad K_{A,B} = \sum_{i=1,N} \frac{k_i \rho}{2A_i^2} \quad (6)$$

14 and the effective mass  $L_{AB}$  is given by

$$15 \quad L_{A,B} = \sum_{i=1,N} \frac{l_i \rho}{A_i} \quad (7)$$

16 Although Equations (6) and (7) are not standard  
 17 expressions for loss and effective mass, they are useful forms  
 18 for the current modeling effort. Equation (5) can be modified  
 19 to include the effects of hull curvature and pressure recovery  
 20 by adjusting the pressures as appropriate. The recovered  
 21 pressure  $P_R$  and hull pressure distribution is included through  
 22 adjustment of the ambient pressures  $P_\infty$  using

$$23 \quad P_R = P_\infty + \frac{1}{2} \rho U_b^2 (C_R + C_P - C_R C_P) \quad (8)$$

1 where  $U_b$  is the boat speed and where the pressure recovery  
2 coefficient  $C_R$  and pressure coefficient  $C_p$  vary between the  
3 inlet recess 12 and shutterway recess 26. For simplicity of  
4 modeling, it is assumed that this pressure acts along the  
5 surface of the submarine hull.

6 If the instantaneous flow rates are known, the seven flow  
7 acceleration equations are generated using Equation (5), the  
8 three conservation of mass equations, Equations (1), (2) and  
9 (4), and the pump performance functions (derived from FIGS. 7  
10 and 8), form a set of equations which can be solved for the  
11 five unknown pressures and five unknown flow accelerations at  
12 a specific time during the launch transient. With the flow  
13 accelerations expressed in terms of the flow rates and  
14 pressures, the equations can be numerically integrated to  
15 develop a time history of internal pressures and flow rates  
16 during a launch.

17 A matrix formulation of the problem,  $Ax=B$ , is as follows  
18 on the successive pages:

$$\begin{bmatrix}
 1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 1 & 0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & 1 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\
 -L_{1,2} & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 \\
 -L_{3,4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 \\
 -L_{4,5} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 \\
 0 & 0 & 0 & -L_{5,6} & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 \\
 0 & 0 & 0 & 0 & -L_{5,8} & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
 0 & 0 & 0 & 0 & 0 & -L_{5,9} & 0 & 0 & 0 & 0 & 1 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & -L_{6,10} & 0 & 0 & 0 & 0 & 1 \\
 0 & -L_{7,1} & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\
 0 & 0 & -L_{5,1} & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 1 & 0
 \end{bmatrix}$$

$$\begin{bmatrix}
 dQ_{1,2}/dt \\
 dQ_{7,1}/dt \\
 dQ_{5,1}/dt \\
 dQ_{5,6}/dt \\
 dQ_{5,8}/dt \\
 dQ_{5,9}/dt \\
 dQ_{6,10}/dt \\
 P_1 \\
 P_2 \\
 P_3 \\
 P_4 \\
 P_5 \\
 P_6
 \end{bmatrix}
 =
 \begin{bmatrix}
 -\frac{d^2 V_1}{dt^2} \\
 -\frac{d^2 V_5}{dt^2} \\
 -\frac{d^2 V_6}{dt^2} \\
 K_{1,2} Q_{1,2}^2 \left[ \frac{Q_{1,2}}{\|Q_{1,2}\|} \right] \\
 f(rpm, t) \\
 K_{3,4} Q_{1,2}^2 \left[ \frac{Q_{1,2}}{\|Q_{1,2}\|} \right] \\
 K_{4,5} Q_{1,2}^2 \left[ \frac{Q_{1,2}}{\|Q_{1,2}\|} \right] \\
 K_{5,6} Q_{5,6}^2 \left[ \frac{Q_{5,6}}{\|Q_{5,6}\|} \right] + P_{R6} \\
 K_{5,8} Q_{5,8}^2 \left[ \frac{Q_{5,8}}{\|Q_{5,8}\|} \right] + P_{R8} \\
 K_{5,9} Q_{5,9}^2 \left[ \frac{Q_{5,9}}{\|Q_{5,9}\|} \right] + P_{R9} \\
 K_{6,10} Q_{6,10}^2 \left[ \frac{Q_{6,10}}{\|Q_{6,10}\|} \right] \\
 K_{7,1} Q_{7,1}^2 \left[ \frac{Q_{7,1}}{\|Q_{7,1}\|} \right] - P_{R7} \\
 K_{5,1} Q_{5,1}^2 \left[ \frac{Q_{5,1}}{\|Q_{5,1}\|} \right]
 \end{bmatrix}
 \quad (9)$$

2

3

4

Many of the loss coefficients and effective masses were derived using two design reports prepared by J. Schwemin of

1 NUWC in 1987. These reports are listed below and incorporated  
2 by reference.

3 Schwemin, J.A., "Comparison of Launcher System Flow Loss  
4 Coefficients for NUSC Land Based Test Facility (Full Size  
5 Impulse Tank) and SSN 21 Actual Ship Condition", Naval  
6 Undersea Systems Center, July 1987; and

7 Schwemin, J.A., "Comparison of Launcher System Water  
8 Masses for NUSC Land Based Test Facility (Full Size Impulse  
9 Tank) and SSN 21 Actual Ship Condition", Naval Undersea  
10 Systems Center, July 1987.

11 The losses which were not taken from this report were the  
12 losses from the shutterway recess 26 to the inlet recess 12,  
13 the loss from the launch tube 24 to the shutterway recess 26,  
14 the loss from the shutterway recess 26 to the guide can 34  
15 with a vehicle 32 passing through an inlet of the guide can  
16 34, the leakage resistance from the shutterway recess 26 to  
17 ambient, and the loss from the inlet recess 12 to the ambient  
18 when the inlet door was shut/removed. All losses were  
19 referenced to a 21-inch diameter flow area.

20 One determination of the present invention is the  
21 assessment of the sensitivity of the shutterway intake  
22 launcher 10 to variations in the launcher loss coefficient.  
23 Consequently, the losses initially selected for the present  
24 invention serve as a design point only. The sensitivity of  
25 the performance of the shutterway intake launcher 10 to  
26 changes about the design point will drive further advances and  
27 modifications to the invention.

1       Phase 3, as shown in FIG. 4, is the initial device exit  
2 from the launch tube 24.

3       As the vehicle 32 begins to exit the launch tube 24, the  
4 effective mass of the section from the point of the launch  
5 tube 24 to the point of the shutterway recess 26 (FIG. 2.)  
6 begins to increase. To correct for this dynamic change, the  
7 first element in the 7<sup>th</sup> row of the matrix in Equation (9)  
8 should be changed to read:

9       
$$A_{7,1} = L_{4,5} + \rho \delta / A \quad (10)$$

10      where A is the area and L is the length and  $\delta$  is the distance  
11 which the vehicle protrudes from the launch tube 24.

12      The effective loss from the launch tube 24 to the  
13 shutterway recess 26 drops significantly during Phase 3 of the  
14 launch because there is no longer a sudden expansion of fluid.  
15 The drag on the nose of the protruding vehicle 32 produces a  
16 pressure drop of approximately one fourth of the sudden  
17 expansion losses.

18      The conservation of mass equations remain unchanged as  
19 the flow from the launch tube 24 is exactly matched by the  
20 displacement of the emerging vehicle 32.

21      Phase 4 is the motion of the vehicle 32 into the guide  
22 can 34 and is shown in FIG. 5. As the nose of the vehicle 32  
23 leaves the shutterway recess 26 and enters the guide-can 34,  
24 rapid changes in the flow of the fluid in the shutterway  
25 intake launcher 10 must be accounted for through the  
26 conservation of mass equations.



1       As in Phase 3 of the launch operation, the effective mass  
2 of fluid between the launch tube 24 and the shutterway recess  
3 26 continues to increase as the vehicle 32 travels through the  
4 launch tube 24. Equation 9 remains applicable during this  
5 phase of the launch operation.

6       The flow of fluid through the launch tube 24 to the  
7 shutterway recess 26 is now governed by the pressure  
8 difference between the launch tube 24 and the guide can 34 and  
9 the dynamic head produced by the motion of the vehicle 32.  
10 The pressure at the guide can 34 includes the effects of ship  
11 motion, shutterway pressure recovery, and transients of the  
12 shutterway intake launcher 10. The loads which arise due to  
13 motion of the vehicle 32 can be approximated using an  
14 effective drag coefficient of 0.25 and the internal flow rate  
15 of the launcher 10 to determine the vehicle speed.

16       The flow of fluid through the primary shutterway 28 is  
17 still driven by the pressure drop across that opening.  
18 However, the loss through that opening is increased  
19 substantially as a result of the presence of the exiting  
20 vehicle 32 as is the effective mass of the fluid in that  
21 region.

22       FIG. 9 shows the measurable geometry of the launch  
23 operation as the vehicle 32 enters the primary shutterway 28.  
24 Initially, the loss coefficient varies with the square of the  
25 effective annular area  $(A_0 - A(s))$ . As the vehicle 32 moves  
26 further into the guide can 34, an added loss proportional to  
27 the penetration depth of the vehicle  $(s)$  must be added.

1        The conservation of mass equations for the shutterway 28  
2   are modified to account for the motion of the vehicle 32. As  
3   the vehicle 32 approaches and begins to enter the guide can  
4   34, fluid is displaced from the primary shutterway 28. The  
5   fluid is either displaced into the shutterway recess 26  
6   directly or flows along a path external to the ship and then  
7   enters the shutterway recess 26 via the secondary shutterway  
8   28 as a leakage path or another leakage path. This fluid  
9   displacement or external flow takes place in a very short time  
10   and can result in unwanted acceleration of the vehicle 32.  
11   Equation 3 can be modified through the second derivative of  
12   the volume term to account for this acceleration.

13        The volume flux into the recesses can be described using

$$14 \quad \dot{V}_6 = A(s) \frac{ds}{dt} \quad (11)$$

15   and

$$16 \quad \dot{V}_s = (A_i - A(s)) \frac{ds}{dt} \quad (12)$$

17        The derivative of the rate of the volume flux is related  
18   to the velocity of the vehicle 32 by

$$19 \quad -\frac{d^2 V_s}{dt^2} + A_i \frac{d^2 s}{dt^2} = \frac{d^2 V_6}{dt^2} = \frac{ds}{dt} \frac{dA(s)}{dt} + A(s) \frac{d^2 s}{dt^2} \quad (13)$$

20   where  $ds/dt$  is the velocity. Because the acceleration of the  
21   vehicle 32 is coupled to the pressures and flow rates of the  
22   shutterway intake launcher 10, (Equation 13) must be  
23   incorporated in the matrix solution (Equation 9). Suitably  
24   formulated equations are

$$\frac{d^2 V_6}{dt^2} = \frac{A(s)}{A_{12}} \frac{dQ_{1,2}}{dt} + \frac{Q_{1,2}^2}{A_{1,2}^2} \frac{dA}{ds} \quad (14)$$

and

$$\frac{d^2 V_5}{dt^2} = \frac{(A_t - A(s))}{A_{12}} \frac{dQ_{1,2}}{dt} - \frac{Q_{1,2}^2}{A_{1,2}^2} \frac{dA}{ds} \quad (15)$$

For this preliminary analysis, a 90 degree cone was assumed for the vehicle nose shape (to simplify calculation of  $A(s)$ ).

Phase 5 is the motion of the vehicle 32 out of the guide can 34 and is shown in FIG. 6. Once the vehicle 32 has cleared the end of the launch tube 24, the dynamics of the launcher 10 revert to the dynamics of Phase 2 between the launch tube 24 and the shutterway recess 26. At this point, the motion dynamics of the vehicle 32 is no longer directly coupled with the internal flow of the launch system 10. The vehicle 32 decelerates based on the pressure difference between the external flow and the shutterway recess 26.

Phase 6 is the weapon clear and is not illustrated. As the vehicle 32 navigates the guide can 34 and the primary shutterway 28, additional transients are expected. However, due to the large areas and volumes at the exit of the primary shutterway 28, these transients will be ignored. The motion of the vehicle 32 is assumed to be uncoupled from the dynamics of the shutterway intake launcher 10 during this phase of the launching operation.

FIG. 10 depicts a comparison of the predicted transient launch velocities for both the base-line configuration based

1 on the prior art of FIG. 1 and for the modified configuration  
2 of the shutterway intake launcher 10 shown in FIG. 2. The  
3 most significant system performance change is the transients  
4 generated as the vehicle 32 exits the tube. These transients  
5 are the result of the assumed behavior of the jet of fluid  
6 which precedes the vehicle 32.

7 Preliminary calculations regarding the shutterway intake  
8 launcher 10 indicate a similar tube exit velocity for both the  
9 baseline and modified systems. Added flow losses associated  
10 with the operation of the shutterway intake launcher 10 are  
11 small.

12 During operation of the shutterway intake launcher 10,  
13 the effective mass of the system is less than the effective  
14 mass of the system during an open loop operation. The water-  
15 hammer effect as the vehicle 32 enters the shutterway 28 can  
16 produce large accelerations and pressure transients in the  
17 shutterway intake launcher 10.

18 Because of the transient effects as the vehicle 32 enters  
19 the shutterway 28, either a means to reduce the added mass of  
20 the guide can 34 must be found or a depth independent  
21 accumulator system must be added to the shutterway intake  
22 launcher 10.

23 The added mass associated with the shutterway 28 can be  
24 reduced by either increasing the area of the inlet recess 12  
25 or by shortening the path from the external flow to the  
26 shutterway recess 26. The path can be reduced by machining  
27 holes somewhere in the boundary between the shutterway recess

1 26 and the external flow. Holes already incorporated into the  
2 shutterways to reduce pressure recovery may provide the mass  
3 reduction needed.

4 The advantages of the shutterway intake launch system 10  
5 include a solution to the reverse-flow problem, and the  
6 provision of a pressure-balanced system.

7 Alternatives to the concept presented herein include: An  
8 inlet door as a part of a launcher system with the lowest  
9 tubes in the submarine torpedo banks isolated from the upper  
10 tubes and also connected to the inlet chamber. As such the  
11 upper tubes can operate in a standard fashion (drawing water  
12 through the inlet door) and the lower tubes can be operated as  
13 the shutterway intake launcher concept. Further, an  
14 accumulator can be added to the system to eliminate any water  
15 hammer effects.

16 This invention has been disclosed in terms of certain  
17 embodiments. It will be apparent that many modifications can  
18 be made to the disclosed apparatus without departing from the  
19 invention. Therefore, it is the intent of the appended claims  
20 to cover all such variations and modifications as come within  
21 the true spirit and scope of this invention.